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(54) **PACKAGING FOR GRATING-BASED WDM ROUTER**

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(58) **Field of Search** **385/37, 51, 24, 385/52; 359/127, 124, 130, 566; 439/700, 824**

(56) **References Cited**

FOREIGN PATENT DOCUMENTS

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* cited by examiner

Primary Examiner—Cassandra Spyrou

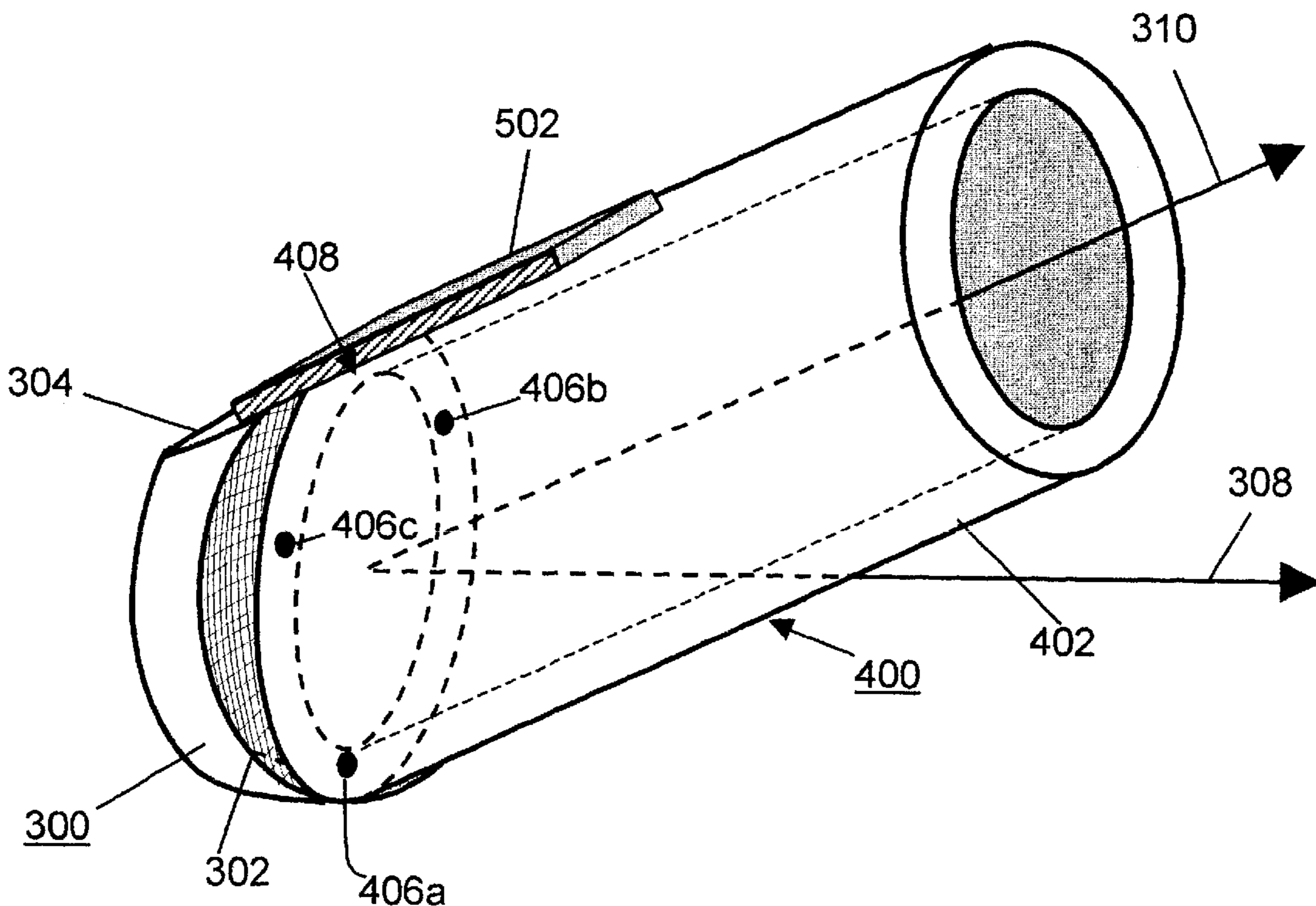
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(57) **ABSTRACT**

The present invention provides a package for a wavelength division multiplexer (WDM). The package includes a grating comprising an alignment surface; a first sleeve comprising a mount, the mount capable of contacting the grating; and an alignment plate coupled to an outer surface of the first sleeve, where the alignment plate is capable of contacting the alignment surface of the grating. The preferred embodiment of the package also includes a second sleeve with a holding mechanism in contact with the grating. This packaging affords a quick, easy, precise and reproducible positioning and alignment of grating. Thus, the WDM is minimized in size while also reproducibly assembled with perfect alignment in a minimal amount of time.

35 Claims, 12 Drawing Sheets



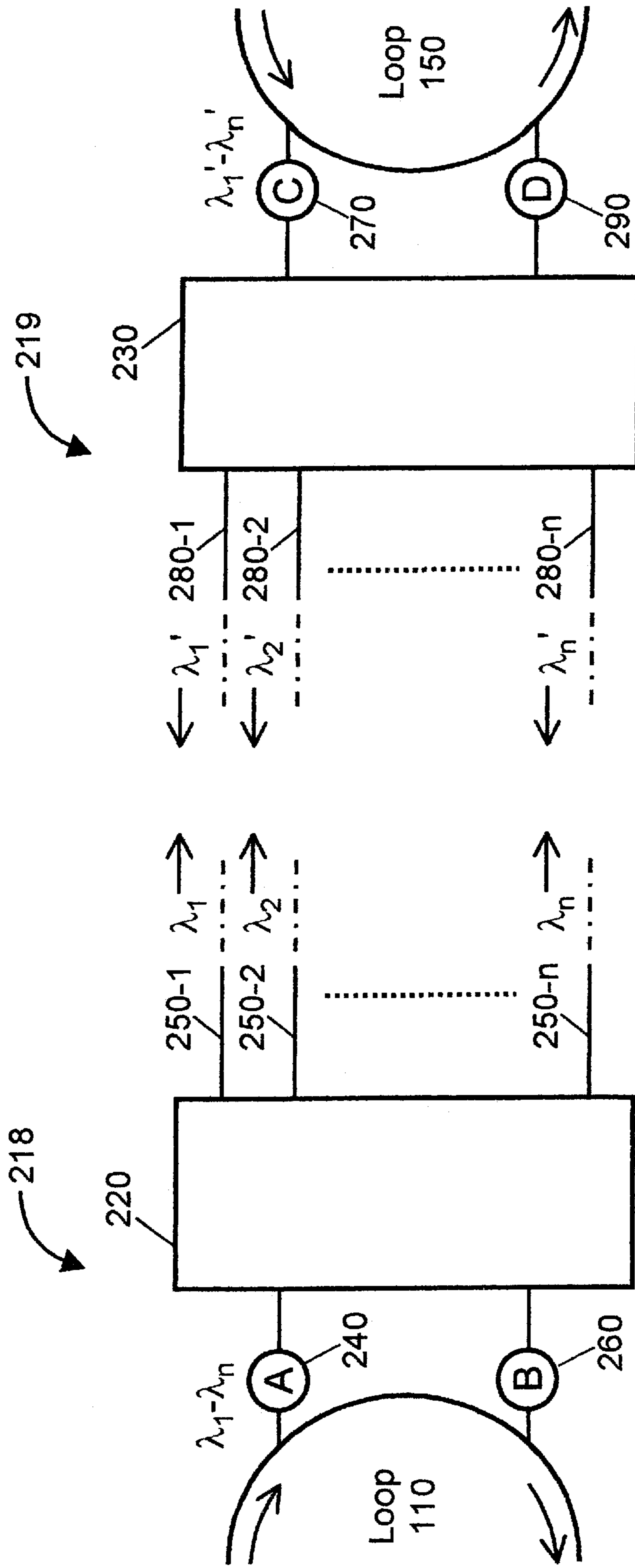


Figure 1a
(Prior Art)

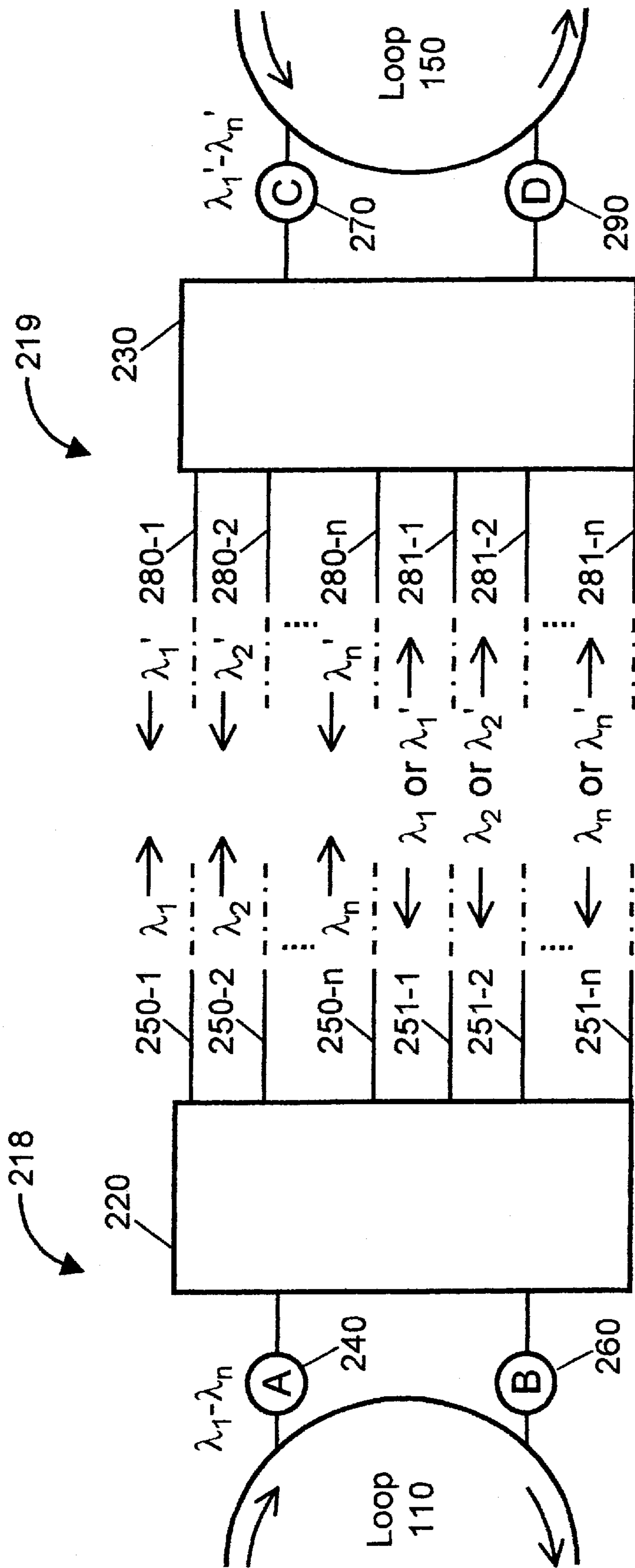


Figure 1b
(Prior Art)

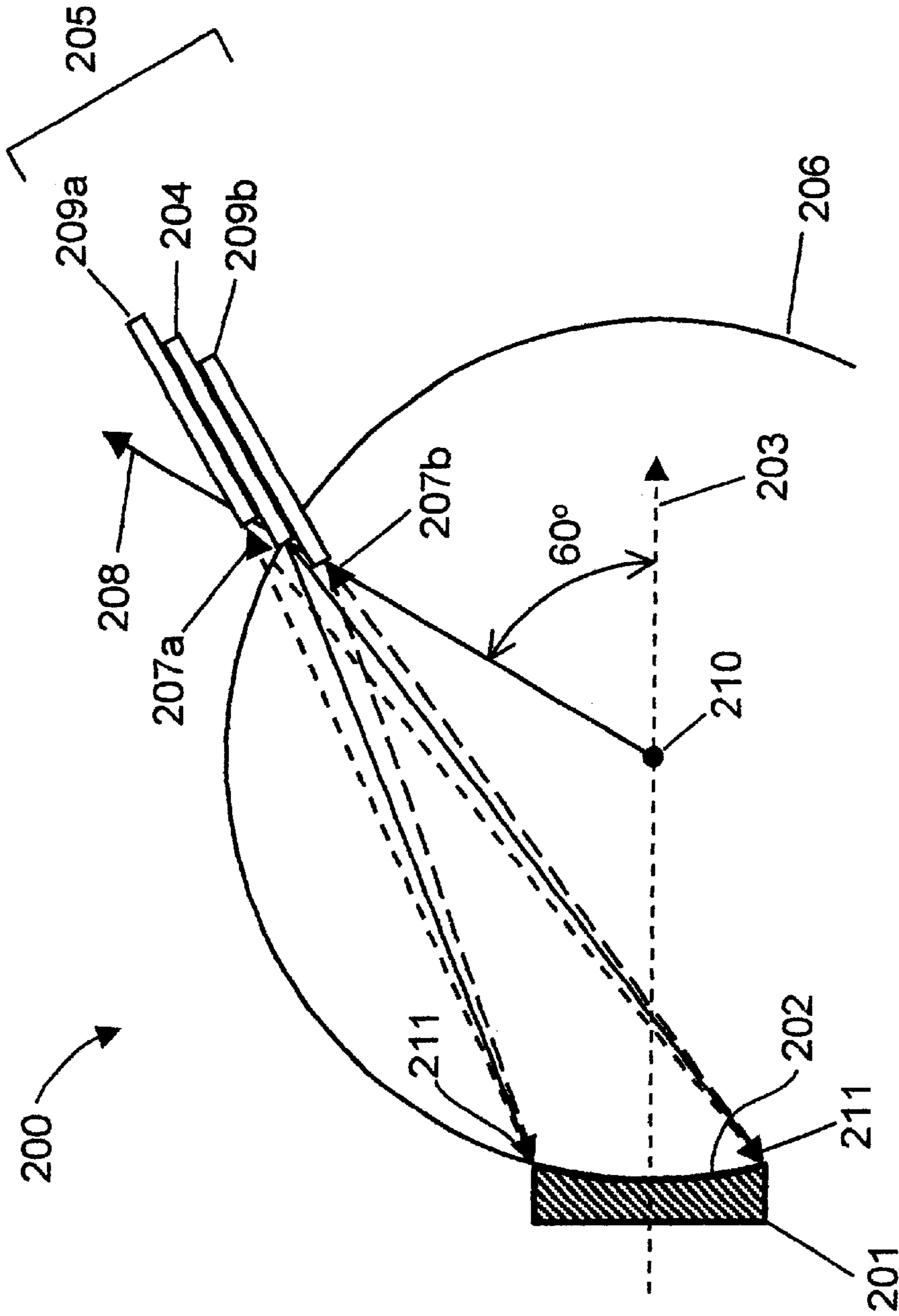


Figure 2a
(Prior Art)

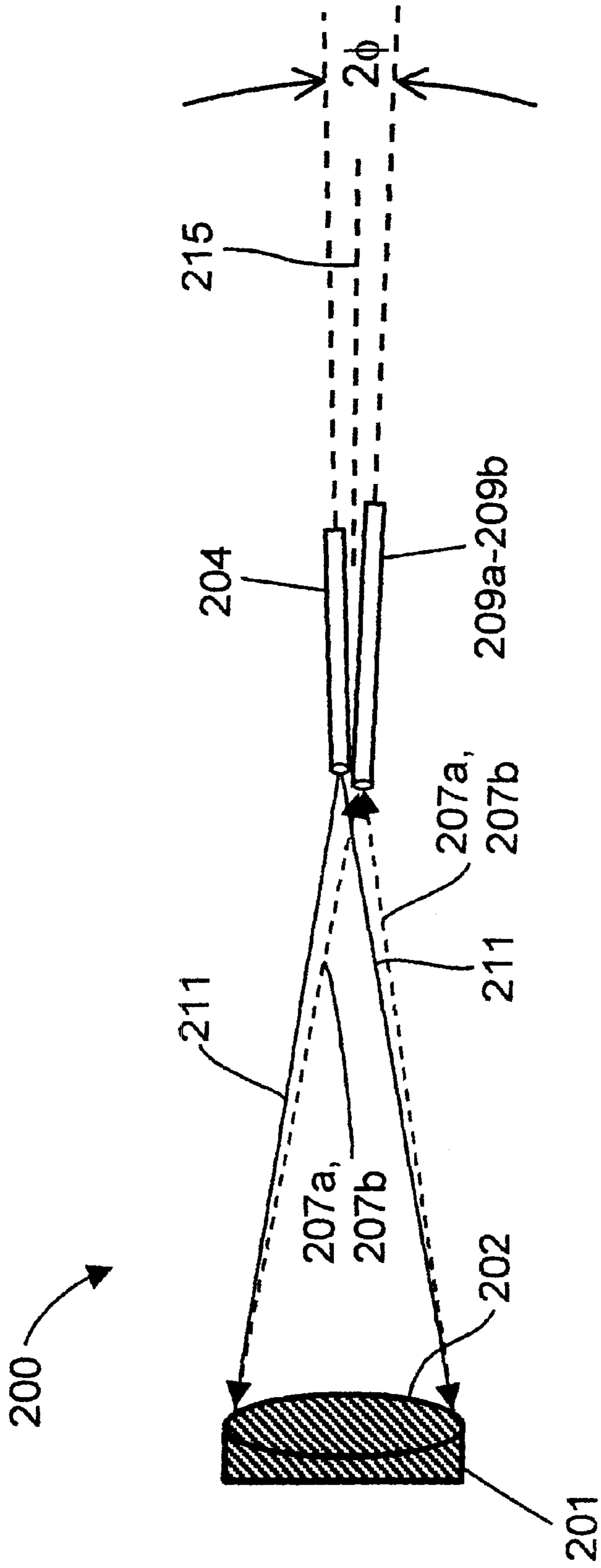


Figure 2b
(Prior Art)

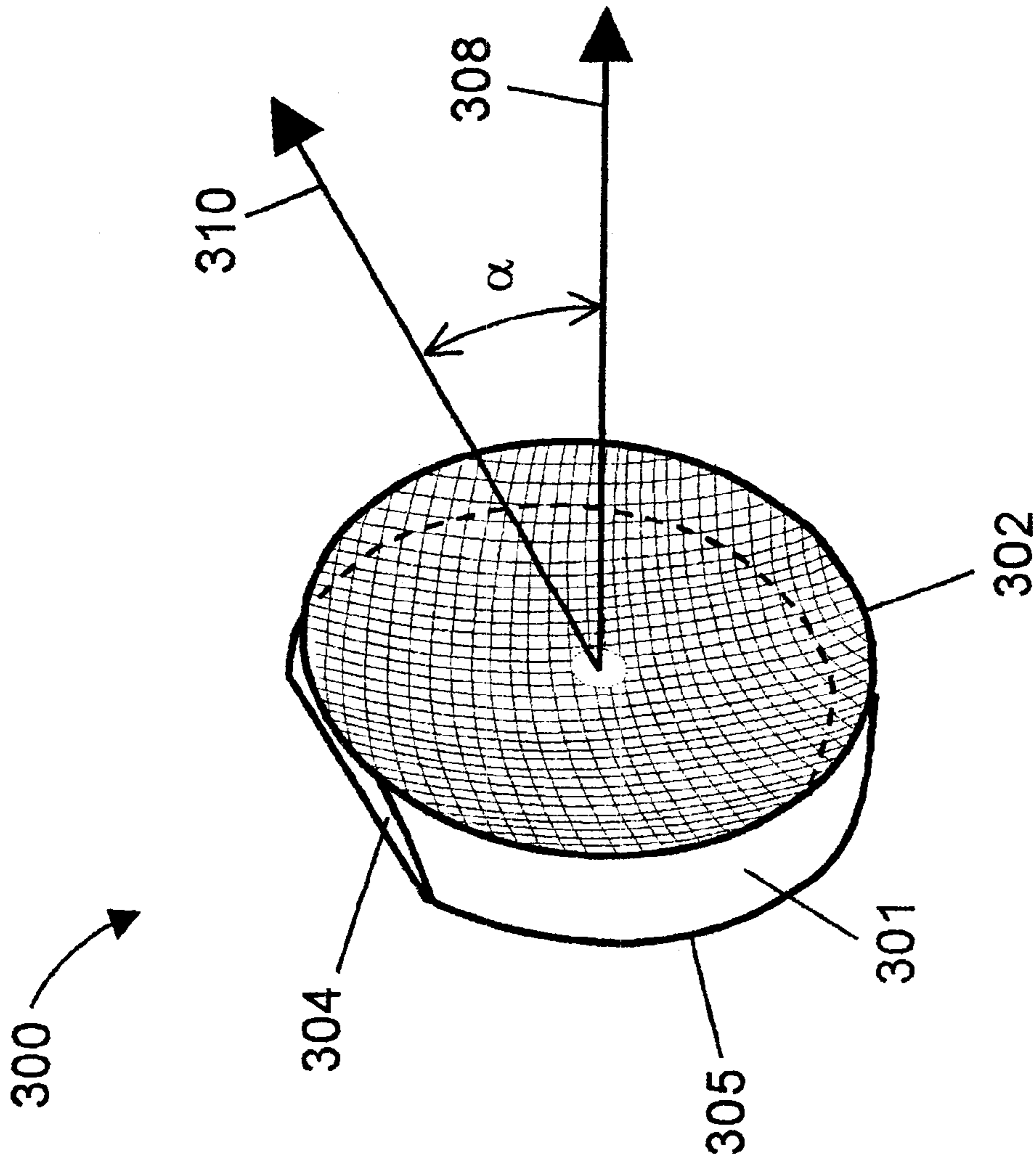


Figure 3

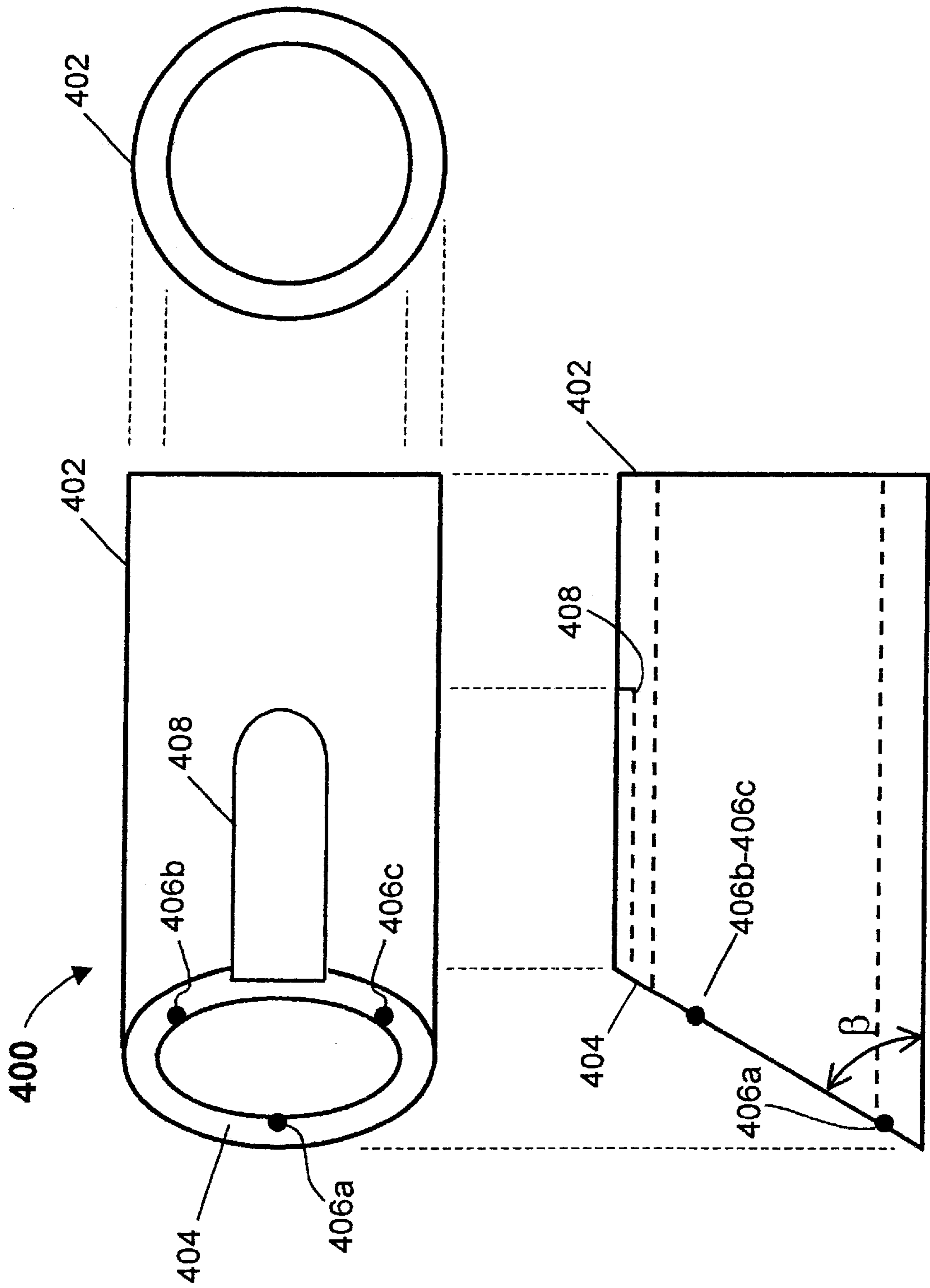


Figure 4

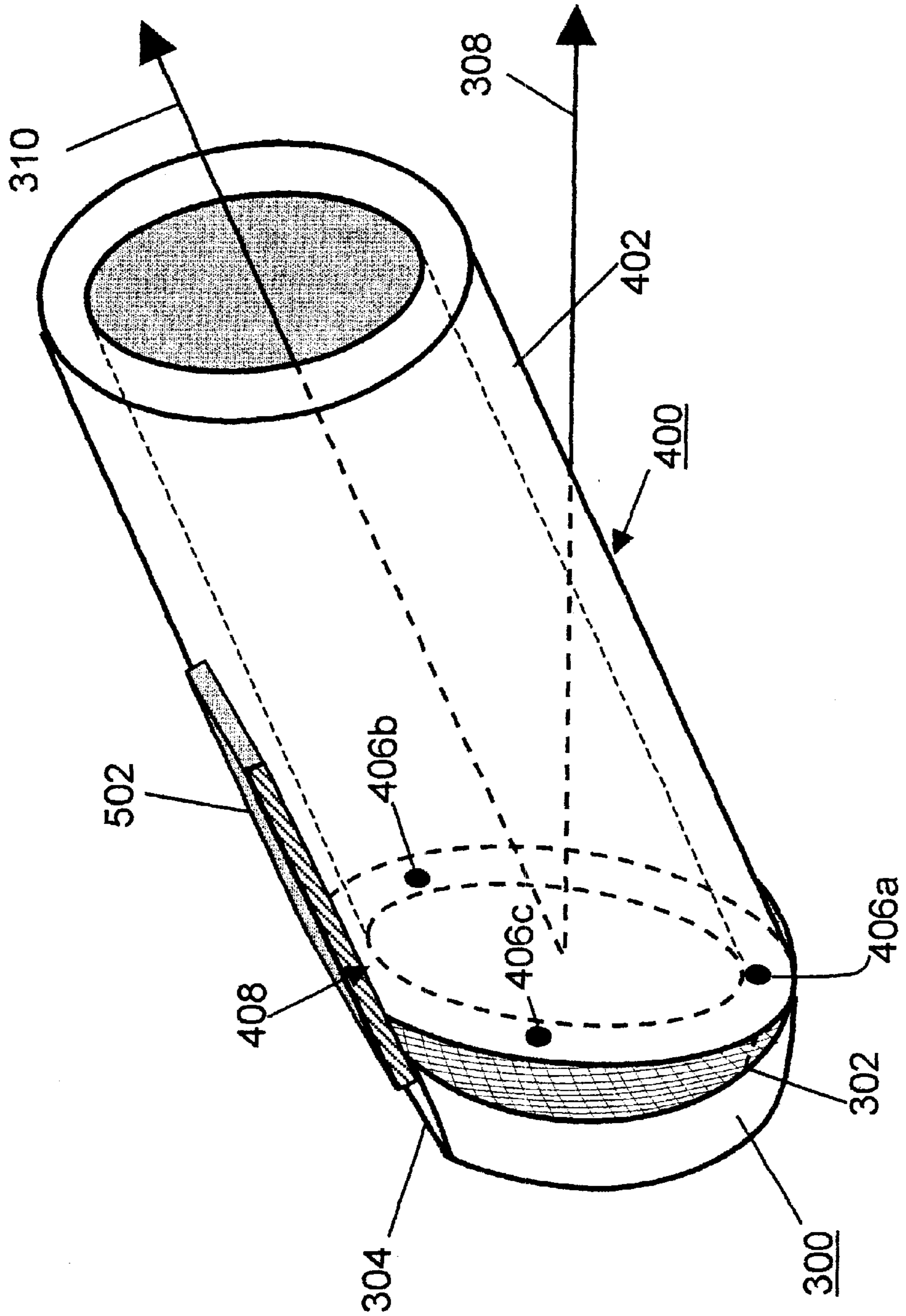


Figure 5

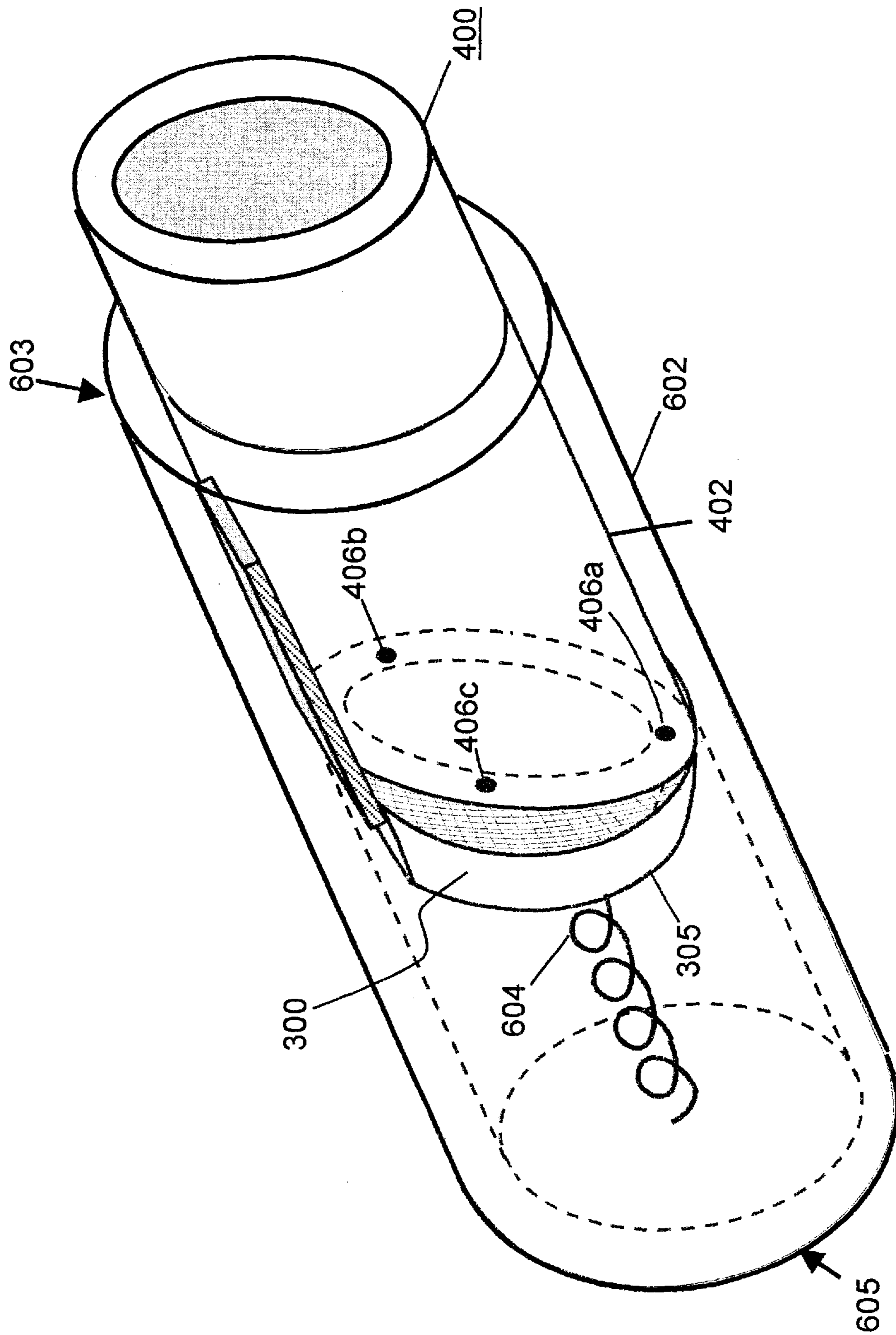


Figure 6

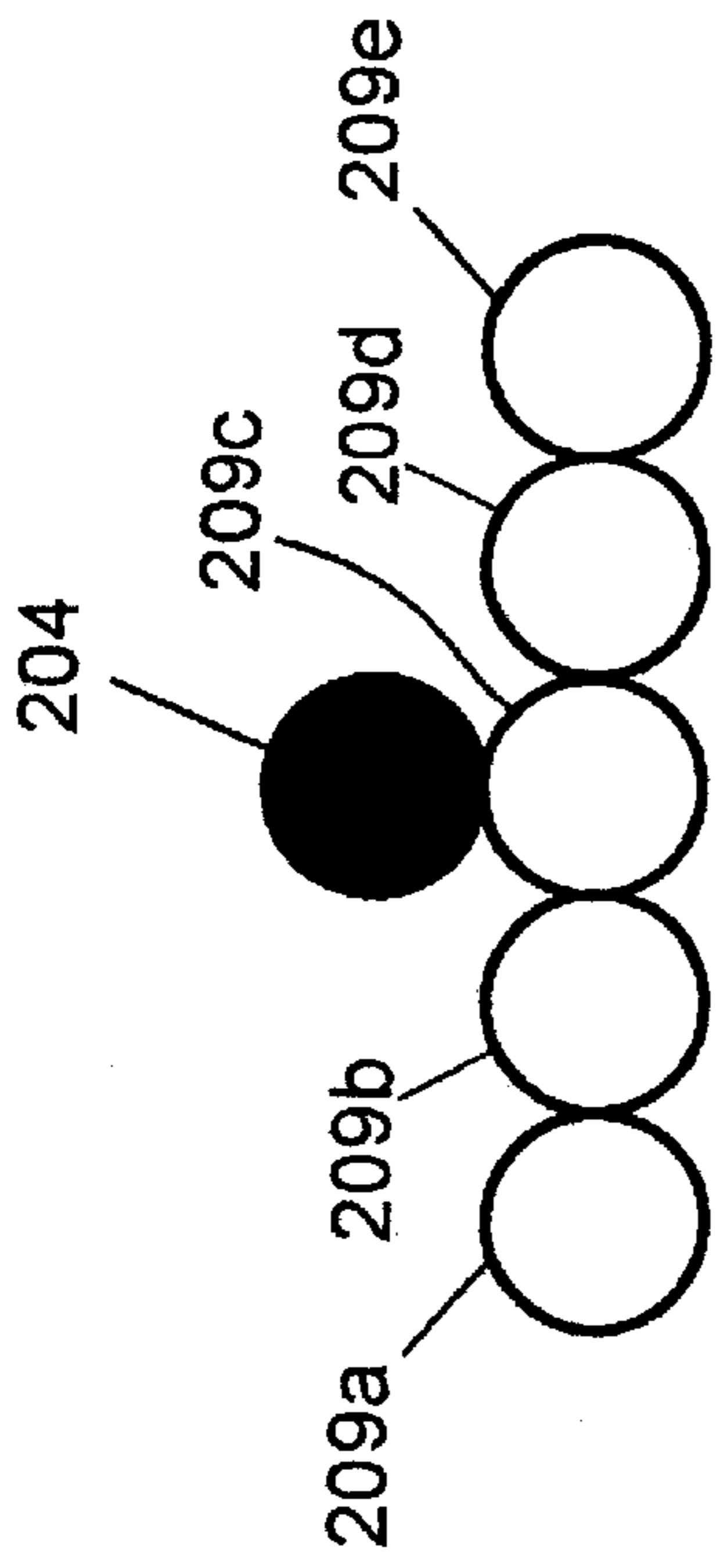


Figure 7a

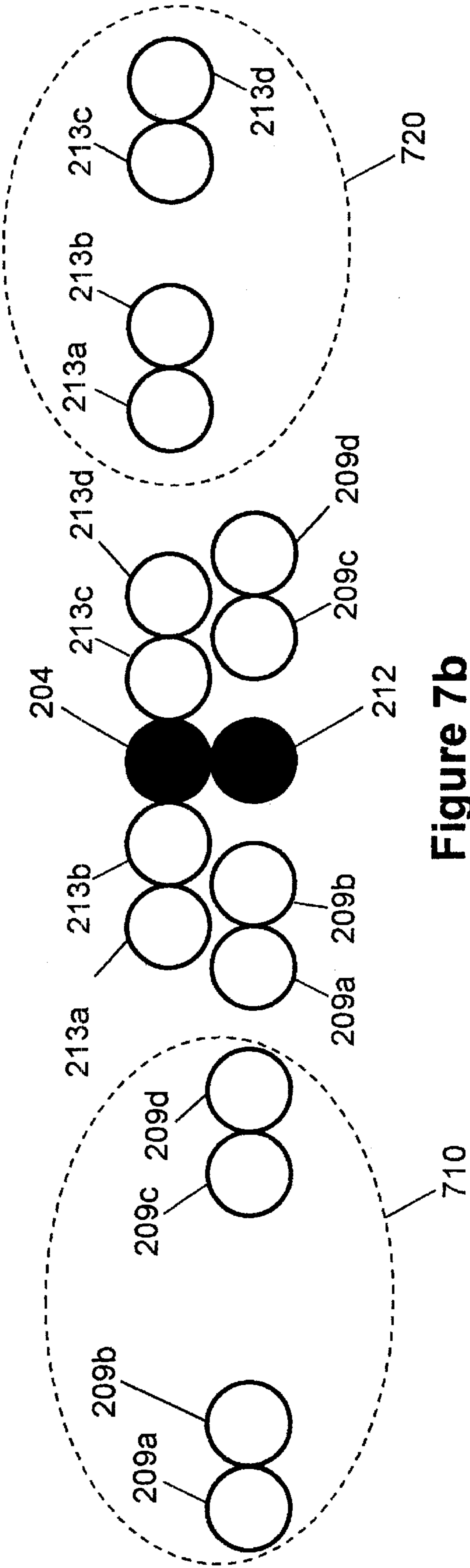


Figure 7b

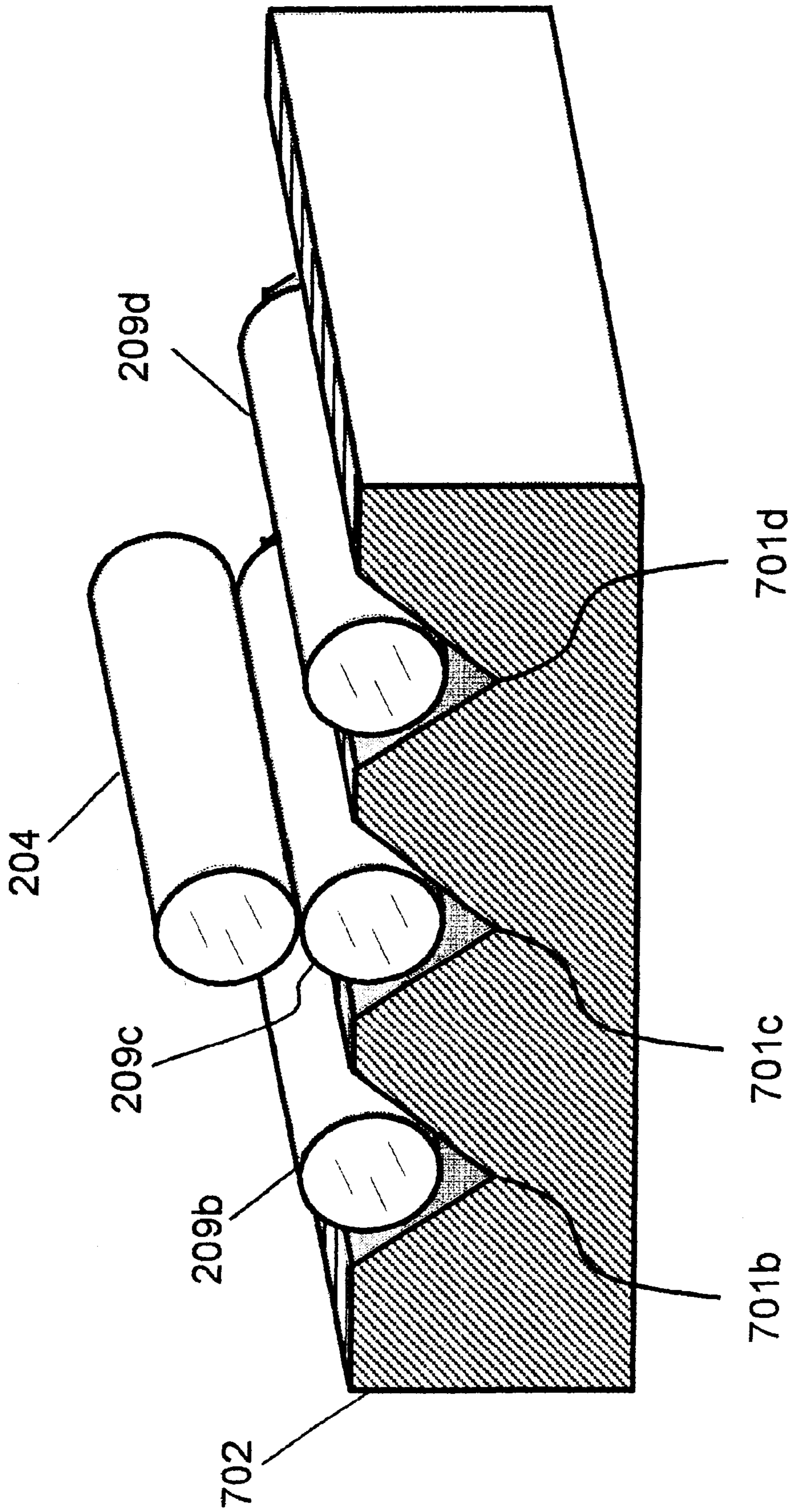
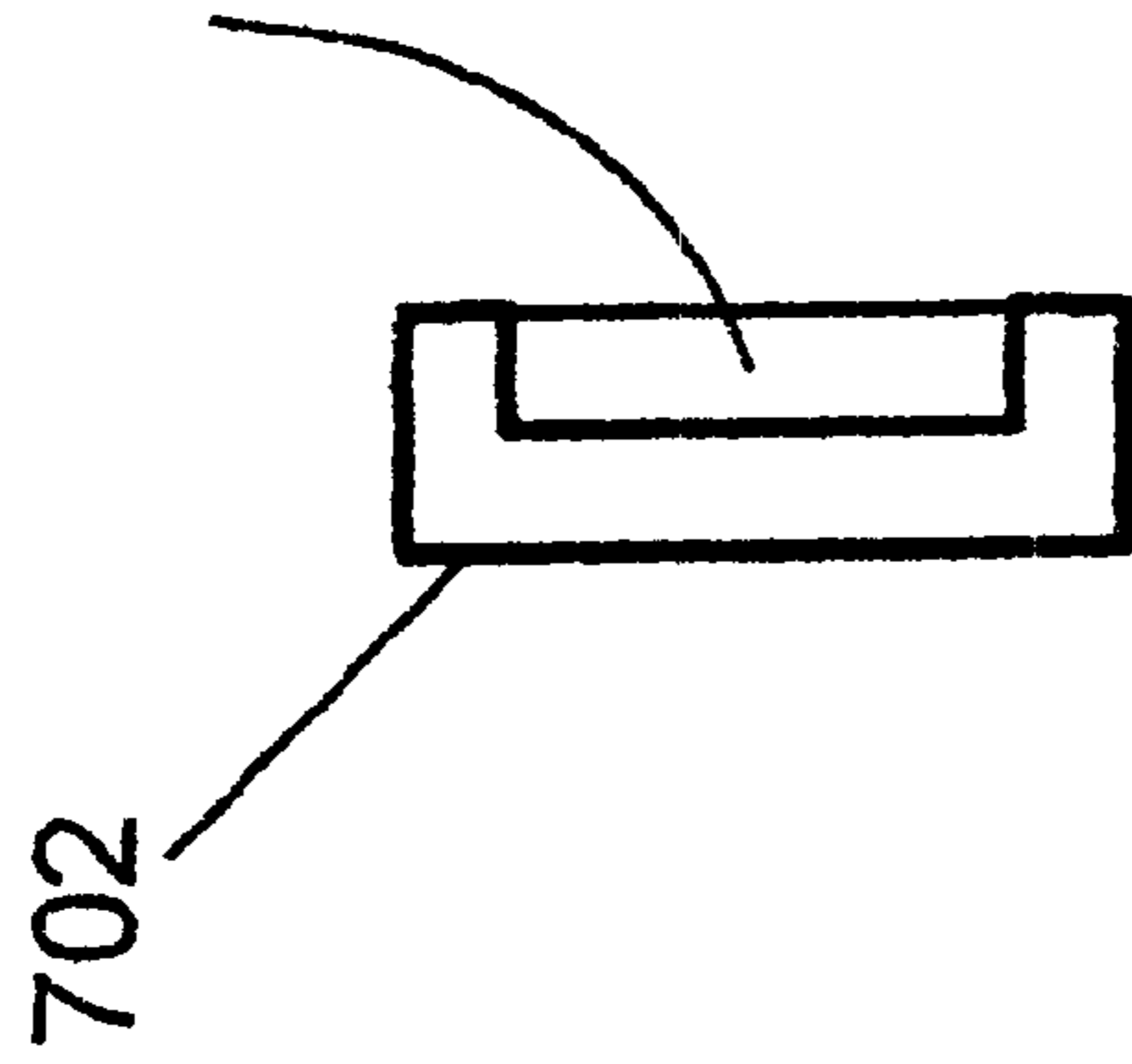


Figure 7c

End View



Side View

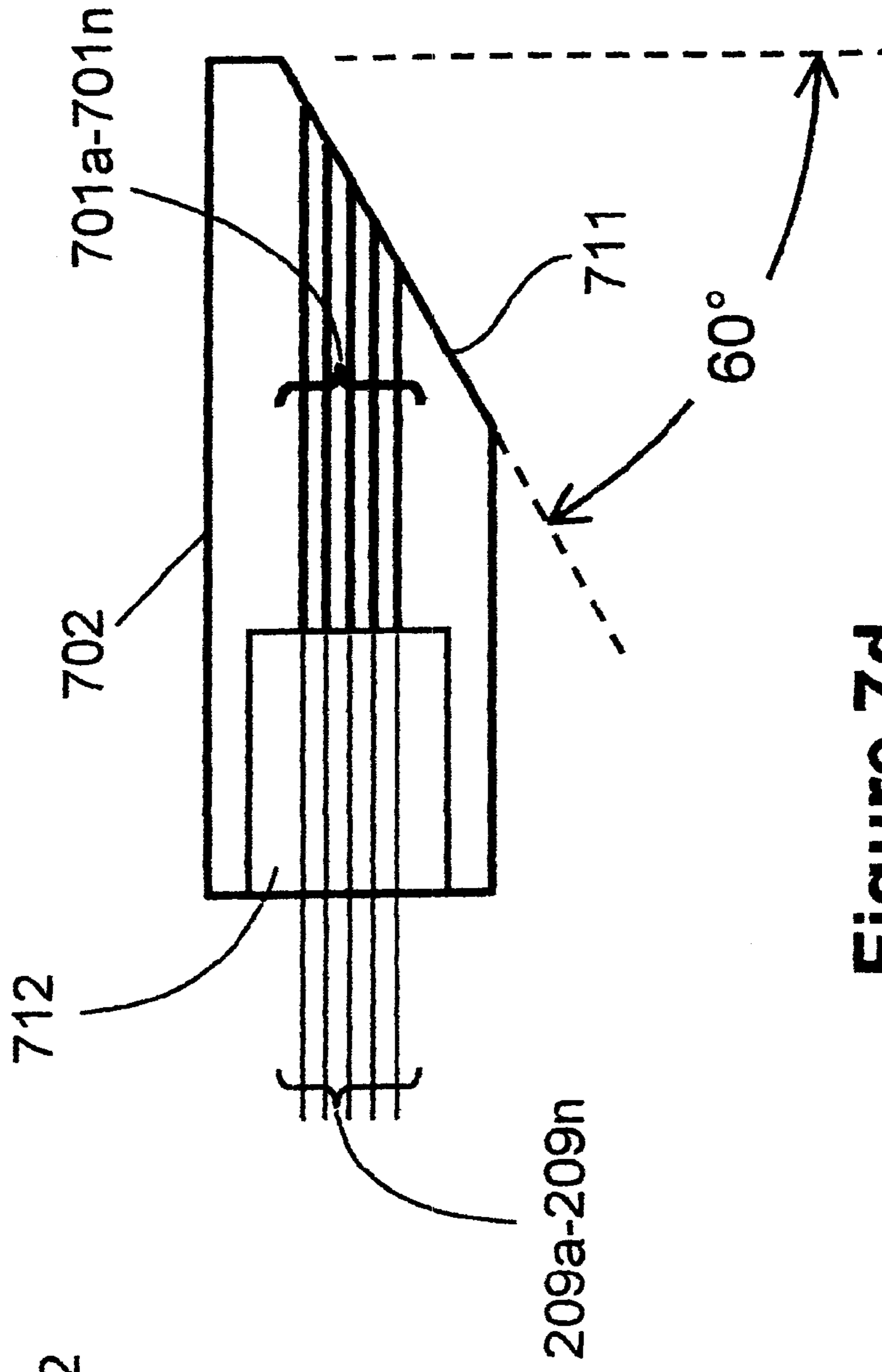


Figure 7d

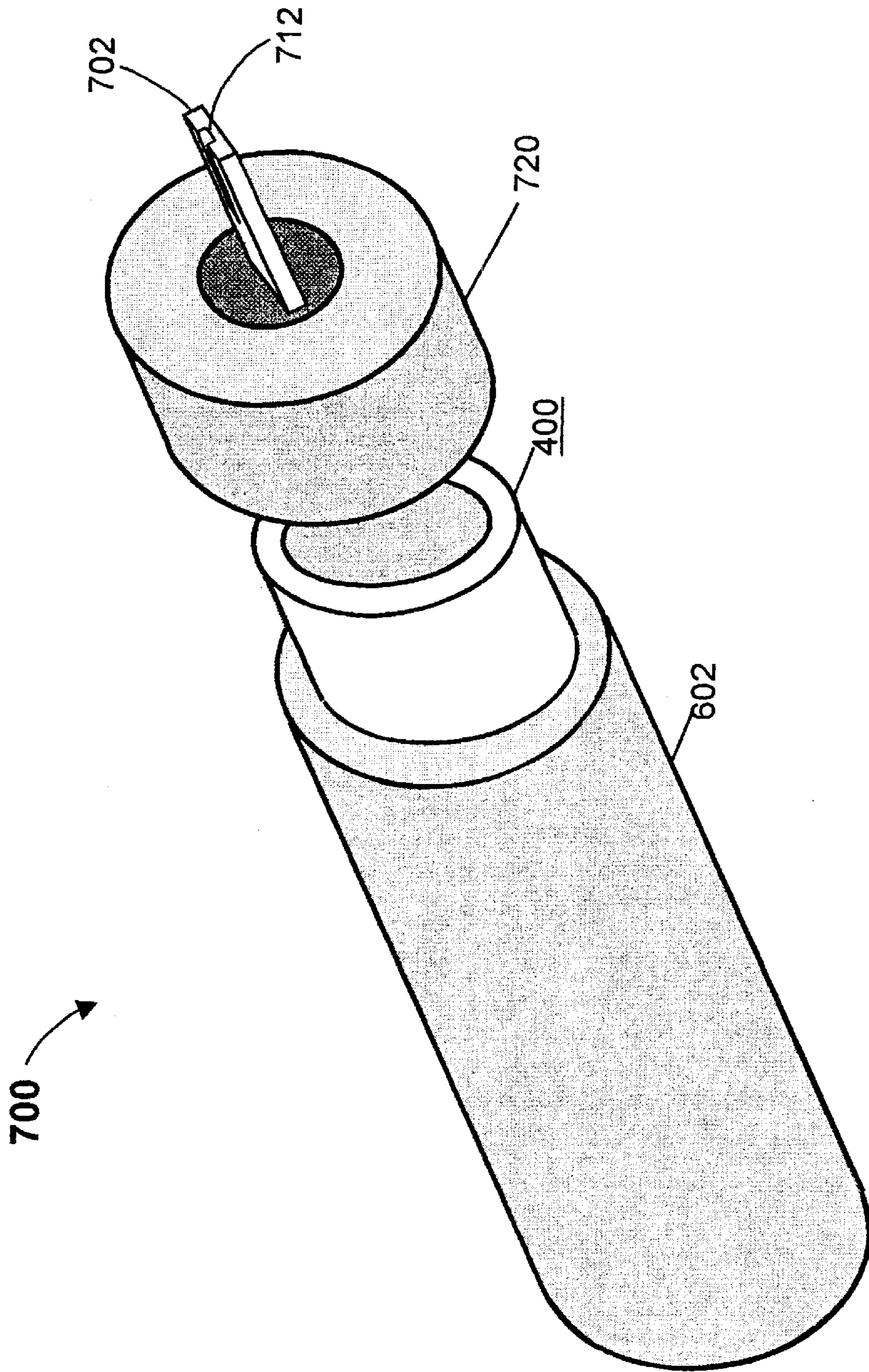


Figure 7e

PACKAGING FOR GRATING-BASED WDM ROUTER

FIELD OF THE INVENTION

The present invention relates to wavelength division multiplexers and demultiplexers in optical communications networks and systems, and more particularly to their packaging.

BACKGROUND OF THE INVENTION

Fiber optic communication systems are becoming increasingly popular for data transmission due to their high speed and high data capacity capabilities. Wavelength division multiplexing is used in such fiber optic communication systems to transfer a relatively large amount of data at a high speed. In wavelength division multiplexing, multiple information-carrying signals, each signal comprising light of a specific restricted wavelength range, may be transmitted along the same optical fiber.

In this document, these individual information-carrying lights are referred to as either "signals" or "channels." The totality of multiple combined signals in a wavelength-division multiplexed optical fiber, optical line or optical system, wherein each signal is of a different wavelength range, is herein referred to as a "composite optical signal."

The term "wavelength," denoted by the Greek letter λ (lambda) is used herein in two senses. In the first usage, this term is used according to its common meaning to refer to the actual physical length comprising one full period of electromagnetic oscillation of a light ray or light beam. In its second usage, the term "wavelength" is used synonymously with the terms "signal" or "channel." Although each information-carrying channel actually comprises light of a certain range of physical Wavelengths, for simplicity, a single channel is referred to as a single wavelength, λ , and a plurality of n such channels are referred to as "n wavelengths" denoted λ_1 - λ_n . Used in this sense, the term "wavelength" may be understood to refer to "the channel nominally comprised of light of a range of physical wavelengths centered at the particular wavelength, λ ."

A crucial feature of fiber optic networks is the separation of the composite optical signal into its component wavelengths or channels, typically by a wavelength division multiplexer. This separation must occur to allow for the exchange of signals between loops within optical communications networks. The exchange typically occurs at connector points, or points where two or more loops intersect for the purpose of exchanging wavelengths.

FIG. 1a schematically illustrates one form of an add/drop system, which typically exists at connector points for the management of the channel exchanges. The exchanging of data signals involves the exchanging of matching wavelengths from two different loops within an optical network. In other words, each composite optical signal drops a channel to the other loop while simultaneously adding the matching channel from the other loop.

A wavelength division multiplexer (WDM) typically performs separation of a composite optical signal into component channels in an add/drop system. Used in its reverse sense, the same WDM can combine different channels, of different wavelengths, into a single composite optical signal. In the first instance, this WDM is strictly utilized as a de-multiplexer and, in the second instance, it is utilized as a multiplexer. However, the term "multiplexer" is typically used to refer to such an apparatus, regardless of the "direction" in which it is utilized.

FIG. 1a illustrates add/drop systems 218 and 219 utilizing wavelength division multiplexers 220 and 230. A composite optical signal from Loop 110 (λ_1 - λ_n) enters its add/drop system 218 at node A (240). The composite optical signal is separated into its component channels by the WDM 220. Each channel is then outputted to its own path 250-1 through 250-n. For example, λ_1 would travel along path 250-1, λ_2 would travel along path 250-2, etc. In the same manner, the composite optical signal from Loop 150 (λ_1' - λ_n') enters its add/drop system 219 via node C (270). The signal is separated into its component channels by the WDM 230. Each channel is then outputted via its own path 280-1 through 280-n. For example, λ_1' would travel along path 280-1, λ_2' would travel along path 280-2, etc.

In the performance of an add/drop function, for example, λ_1 is transferred from path 250-1 to path 280-1. It is combined with the others of Loop 150's channels into a single new composite optical signal by the WDM 230. The new signal is then returned to Loop 150 via node D 290. At the same time, λ_1' is transferred from path 280-1 to path 250-1. It is combined with the others of Loop 110's channels into a single new composite optical signal by the WDM 220. This new signal is then returned to Loop 110 via node B (260). In this manner, from Loop 110's frame of reference, channel λ_1 of its own signal is dropped to Loop 150 while channel λ_1' of the signal from Loop 150 is added to form part of its new signal. This is the add/drop function.

FIG. 1b illustrates a second form by which add/drop systems 218 and 219 may be configured. In FIG. 1b, each WDM is optically coupled to a first plurality of paths through which channels are outputted and to a second plurality of paths through which signals are inputted. For instance, the paths 250-1, 250-2, . . . , 250-n are utilized to output signals comprising wavelengths λ_1 , λ_2 , . . . , λ_n , respectively, from the WDM 220 and the paths 251-1, 251-2, . . . , 251-n are utilized to input signals comprising such wavelengths to the WDM 220. Likewise, as shown in FIG. 1b, the paths 280-1, 280-2, . . . , 280-n are utilized to output signals λ_1' , λ_2' , . . . , λ_n' (comprising the physical wavelengths λ_1 , λ_2 , . . . , λ_n) respectively, from the WDM 230 and the paths 281-1, 281-2, . . . , 281-n are utilized to input signals comprising such wavelengths to the WDM 230.

FIGS. 2a and 2b illustrate a top view and side view, respectively, of a prior-art grating-based WDM. In the WDM 200, a concave reflection-type holographic grating 202 is disposed upon a substrate plate or block 201 comprised of a material with low thermal expansion. The grating 202, which comprises a portion of a spherical surface 206 centered at point 210, receives a wavelength-division multiplexed composite optical signal 211 input to the WDM 200 from an input fiber 204. The composite optical signal 211 is comprised of a plurality of individual channels, λ_1 , λ_2 , The concave grating 202 diffracts, reflects, focuses and spatially disperses each of these individual channels according to its respective wavelength such that each channel is directed to exactly one of a plurality of output fibers 209a-209b. For instance, referring to FIG. 2a, if input signal 201 is comprised of two channels, namely channel λ_1 (207a) and channel λ_2 (207b), with $\lambda_1 < \lambda_2$, then, upon back-diffraction from grating 202, the λ_1 channel (207a) and the λ_2 channel (207b) are focused onto the end of fiber 209a and fiber 209b, respectively.

The input fiber 204 and the plurality of output fibers 209a-209c are disposed within an array 205 of fibers. The end faces of the fibers in array 205 are disposed along or parallel to a plane 208 which makes an angle of 60° with the line 203 that is normal to the grating 202 at the center of the

grating **202**. With this disposition, the grating **202** diffracts light according to the Littrow configuration, in which the angles of incidence and diffraction are approximately equal. FIG. **2b** shows a side view of the prior art apparatus taken parallel to the fiber **204**. FIG. **2b** shows that the fibers are directed towards the grating vertex and are at an angle to the grating dispersion plane **215**. The input fiber **204** and the output fibers **209a–209c** each make the same angle ϕ (taken without regard to algebraic sign) with respect to the dispersion plane **215** and the input fiber **204** makes an angle of 2ϕ with respect to the plane of the output fibers. With channels spaced at 0.33 nm, fiber-to-fiber losses the grating-based WDM router **200** can be maintained at less than 1 dB and ultra-low crosstalk can be maintained.

For use in commercial optical communications systems, the WDM's packaging must be configured such that the size of the apparatus is minimized while also such that the apparatus can be reproducibly assembled with perfect alignment in a minimal amount of time. Furthermore, the device must be packaged or mounted in such a fashion that there is minimal temperature sensitivity. These conditions are problematic since, not only must the grating be positioned precisely with respect to the input and output optical fibers, but also must the angle of the fibers relative to the grating surface and the rotation of the grating surface about its optical axis be precisely and accurately controlled. Slight mis-alignment of the grating and the fibers or of the tilt or rotation of the grating can lead to severe insertion loss and cross talk penalties.

Accordingly, there exists a need for an improved packaging for a grating-based wavelength division multiplexer. The packaging should afford quick, easy, precise, and reproducible positioning and alignment of the grating in the WDM. The present invention addresses such a need.

SUMMARY OF THE INVENTION

The present invention provides a package for a wavelength division multiplexer (WDM). The package includes a grating comprising an alignment surface; a first sleeve comprising a mount, the mount capable of contacting the grating; and an alignment plate coupled to an outer surface of the first sleeve, where the alignment plate is capable of contacting the alignment surface of the grating. The preferred embodiment of the package also includes a second sleeve with a holding mechanism in contact with the grating. This packaging affords a quick, easy, precise and reproducible positioning and alignment of grating. Thus, the WDM is minimized in size while also reproducibly assembled with perfect alignment in a minimal amount of time.

BRIEF DESCRIPTION OF THE FIGURES

FIG. **1a** and FIG. **1b** illustrate two configurations of conventional add/drop systems utilizing wavelength division multiplexers.

FIGS. **2a** and **2b** illustrate a top and a side view, respectively, of a prior-art grating-based WDM employing a concave holographic grating in stationary anastigmatic Littrow configuration.

FIG. **3** illustrates, in perspective view, a concave holographic grating block in a packaging of a WDM in accordance with the present invention.

FIG. **4** illustrates a grating mounting block utilized in conjunction with the concave holographic grating in the packaging of the WDM in accordance with the present invention.

FIG. **5** illustrates a perspective view of a concave holographic grating disposed adjacent to a grating mounting block in the packaging of the WDM in accordance with the present invention.

FIG. **6** illustrates further details of the assembly and alignment of the grating block within the packaging of the WDM in accordance with the present invention.

FIGS. **7a** and **7b** illustrate end views of input and output fibers in two possible configurations of a fiber array of the WDM in accordance with the present invention.

FIG. **7c** illustrates the precise alignment of fibers in the single planar array configuration of the packaging in the WDM in accordance with the present invention.

FIG. **7d** illustrates an end view and a side view of the fiber alignment block in the packaging of the WDM in accordance with the present invention.

FIG. **7e** illustrates a perspective view of the assembled packaging of the WDM in accordance with the present invention.

DETAILED DESCRIPTION

The present invention provides an improved packaging for a grating-based wavelength division multiplexer (WDM). The following description is presented to enable one of ordinary skill in the art to make and use the invention and is provided in the context of a patent application and its requirements. Various modifications to the preferred embodiment will be readily apparent to those skilled in the art and the generic principles herein may be applied to other embodiments. Thus, the present invention is not intended to be limited to the embodiment shown but is to be accorded the widest scope consistent with the principles and features described herein.

A preferred embodiment of a packaging for a grating-based WDM in accordance with the present invention comprises a concave holographic reflection grating with an alignment surface, a first hollow sleeve or cylinder with a mount for contacting the concave holographic reflecting grating and alignment surface, a pin or plate to align the alignment surfaces of the grating and the first hollow sleeve or cylinder, and a second hollow sleeve or cylinder with a spring-loaded holding mechanism in contact with the back side of the grating substrate. To more particularly describe the features of the present invention, please refer to FIGS. **3** through **7e** in conjunction with the discussion below.

FIG. **3** illustrates, in perspective view, a concave holographic grating block in a packaging of a WDM in accordance with the present invention. The grating block **300** comprises a diffraction grating **302** disposed on the concave surface of a substrate plate **301**. The grating **302** comprises a reflective concave surface or film in the geometric form of a spherical cap. The substrate **301** is preferably comprised of a low-thermal-expansion substrate such as Zerodur® glass (manufactured by Schott Glass Technologies, Inc. of Duryea Pa. USA) or ULE® glass (manufactured by Corning, Inc. of Corning N.Y. USA).

The grating axis **308** is perpendicular to the chord to spherical cap grating surface **302** at the center of this surface. The back surface **305** of substrate plate **301** is opposite to the grating surface **302** and is utilized to accept force from a pressure mechanism as described further below. In a preferred embodiment, the back surface **305** is substantially flat and substantially perpendicular to the grating axis **308**, although this need not be the case. An additional flat alignment surface **304** is formed or cut within substrate plate

301 at an oblique angle with respect to the plane comprising the chord to the concave spherical cap grating surface **302**.

A plurality of holographically formed grooves or Bragg diffraction surfaces is disposed upon or within the grating **302**. The grooves or Bragg surfaces comprise the light scattering elements of grating **302** and represent an interference fringe pattern produced using the well-known technique of holography. The grooves or Bragg surfaces of grating **302** are disposed such that the grating **302** operates in the Littrow configuration—that is, such that light rays delivered to the grating **302** and light rays diffracted from the grating **302** are substantially parallel to a single axis **310** disposed at a particular angle α to the grating axis. In a preferred embodiment, the angle α is equal to 30° . Additionally, the surface **302** is optically reflective and is concave so that signal rays are focused after diffracting therefrom.

FIG. 4 illustrates a grating mounting block utilized in conjunction with the concave holographic grating in the packaging of the WDM in accordance with the present invention. The mounting block **400** comprises a hollow rod **402** of a low-thermal-expansion material such as Zerodur® or ULE® glass. The rod **402** is cylindrical in cross section, although this need not be the case. A slanted surface **404** is cut or formed at one end of rod **402** and carries a plurality of rounded mounting pins or mounting balls **406a–406c**. In the preferred embodiment, three mounting pins are used. The slant angle β that the surface **404** makes with the axis of the rod **402** is substantially equal to the complement of the angle of incidence of input signal light rays delivered to the grating **302** in Littrow configuration. In the preferred embodiment, the angle β is 60° . Further, a groove or slot **408** is cut or formed on the outer side surface of hollow rod **402**.

FIG. 5 illustrates a perspective view of a concave holographic grating disposed adjacent to a grating mounting block in the packaging of the WDM in accordance with the present invention. The three rounded mounting pins or mounting balls **406a–406c** comprise the sole contact points between the grating surface **302** and the mounting block **400**. With grating block **300** positioned against the mounting block **400**, the axis or long direction of hollow rod **402** is aligned substantially parallel to the Littrow axis **310** as shown in FIG. 5. Since the grating surface **302** is spherical and the grooves or Bragg surfaces within grating **302** are substantially parallel, the required precision of the lateral alignment between surface **302** and the three mounting pins or balls **406a–406c** is not great. However, the rotational alignment of grating **302** about its axis **308** must be strictly controlled. For this reason, a rotational alignment pin or plate **502** is disposed so as to contact both the alignment surface **304** of grating block **300** and the groove or slot **408** of hollow rod **402**. The rotational alignment pin or plate **502** locks the rotational alignment of grating surface **302** such that the Littrow axis **310** is substantially parallel to the long axis of hollow rod **402**.

During device assembly, the alignment pin or plate **502** is secured to rod **402** by adhesive, epoxy, solder, or the like. Subsequently, the grating block **300** is positioned such that grating surface **302** firmly contacts the three mounting pins or balls **406a–406c** while, simultaneously, the flat surface **304** contacts the alignment pin or plate **502**.

FIG. 6 illustrates further details of the assembly and alignment of the grating block within the packaging of the WDM in accordance with the present invention. The grating block **300** is housed within an outer protective tube or sleeve **602**. The tube or sleeve **602** is open only at its front end **603**

and is sealed at its back end **605**. For clarity of presentation, the tube or sleeve **602** is shown as transparent in FIG. 6 so as to reveal the disposition of the components inside. The inner diameter of the protective tube or sleeve **602** is large enough to fit over at least a portion of the hollow rod **402**. A holding mechanism **604** housed within the protective tube or sleeve **602** applies force to the back face **305** of grating block **300**. In the preferred embodiment, the holding mechanism **604** is spring-loaded. This force is such that, when sleeve **602** is fitted over rod **402**, the spring mechanism **604** forces the grating block **300** into its proper alignment against the pins or balls **406a–406c** and the alignment pin or plate **502**. Thus, the positioning mechanism illustrated in FIG. 5 and FIG. 6 affords quick, easy, precise and reproducible positioning and alignment of grating block **300**.

FIGS. 7a and 7b illustrate end views of input and output fibers in two possible configurations of a fiber array of the WDM in accordance with the present invention. FIG. 7a and 7b respectively illustrate a single planar array and a double planar array configuration of the fibers comprising fiber array **205**. In both FIG. 7a and FIG. 7b, fiber **204** is an input/output fiber that carries, either as input or output, a wavelength division multiplexed composite optical signal and fibers **209a–209e** are a plurality of output/input fibers wherein each such fiber carries, either as output or input, a single signal comprising an individual wavelength. In FIG. 7b, fiber **212** is a second input/output fiber corresponding to fiber **204** and fibers **213a–213d** are a second plurality of output/input fibers corresponding to the set **209a–209d**.

In the single planar array embodiment shown in FIG. 7a, the fibers **209a–209e** are all disposed within a plane that is at an angle ϕ (≥ 0) with respect to the dispersion plane of grating **302** and the fiber **204** is to the opposite side of the dispersion plane and is disposed at an angle of $-\phi$ (≤ 0) with respect to the dispersion plane. In the double planar array embodiment shown in FIG. 7b, the fibers **204**, **213a–213d** are all disposed within a first plane, and the fibers **212**, **209a–209d** are all disposed within a second plane wherein the second and first planes are disposed at an angle ϕ (≥ 0) and at an angle $-\phi$ (≤ 0) to the grating dispersion plane, respectively. The centers of the end faces of all fibers are disposed within the plane **208** (FIG. 2a) in either the single or double planar array configuration. The spacings between fibers within either the first or second plane need not be regular, and the inter-fiber spacings within the first plane need not be the same as those within the second plane. The fibers **209a–209d** comprise a first set **710** of output/input fibers and the fibers **213a–213d** comprise a second set **720** of output/input fibers.

When the WDM in accordance with the present invention is operated as a de-multiplexer with respect to a composite optical signal on input/output fiber **204**, a wavelength division multiplexed composite optical signal is input to the WDM through input/output fiber **204**, the composite optical signal is separated into its individual component signals by the grating **302**, the separated signals are spatially dispersed by the grating **302** according to their respective wavelengths, and each individual signal is directed and focused onto a different respective fiber of the plurality of output/input fibers **209a**, **209b**, **209c** The individual signals are then output from the WDM along respective individual output/input fibers of the set **209a**, **209b**, **209c** When the WDM is operated as a multiplexer with respect to signals on output/input fibers **209a**, **209b**, **209c** individual signals are input to the WDM from respective individual fibers of the plurality of output/input fibers **209a**, **209b**, **209c**, the signals are diffracted by the grating **302**

along a single direction so as to be combined into a single composite optical signal and the composite optical signal is focused onto the end of the input/output fiber **204** so as to be output from the WDM therein.

Likewise, when the WDM in accordance with the present invention is operated as a de-multiplexer with respect to a composite optical signal on input/output fiber **212**, a wavelength division multiplexed composite optical signal is input to the grating **302** through input/output fiber **212**, the composite optical signal is separated into its individual component signals by the grating **302**, the separated signals are spatially dispersed by the grating **302** according to their respective wavelengths, and each individual signal is directed and focused onto a different respective fiber of the plurality of output/input fibers **213a**, **213b**, **213c** . . . The individual signals are then output from the WDM along respective individual output/input fibers of the set **213a**, **213b**, **213c** . . . When the WDM is operated as a multiplexer with respect to signals on the output/input fibers **213a**, **213b**, **213c** . . . , individual signals are input to the WDM from respective individual fibers of the plurality of output/input fibers **213a**, **213b**, **213c** . . . , the signals are diffracted by the grating **302** along a single direction so as to be combined into a single composite optical signal and the composite optical signal is focused onto the end of the input/output fiber **212** so as to be output from the WDM therein.

The embodiments of the WDM in accordance with the present invention associated with the double planar array illustrated in FIG. **7b** have the advantage that the WDM may be utilized as a de-multiplexer with respect to one set of fibers (e.g., fibers **204**, **209a**, **209b**, **209c**, etc.) simultaneously while it is being utilized as a multiplexer with respect to the second set of fibers (e.g., **212**, **213a**, **213b**, **213c**, etc.) and vice versa. Also, both sets of fibers may be used simultaneously in either the multiplexer or the de-multiplexer configuration. These simultaneous arrangements are permitted because each set of fibers can perform the multiplexing or de-multiplexing function essentially independently of the other set of fibers as a result of the extremely low inter-fiber cross-talk characteristics of the apparatus.

FIG. **7c** illustrates the precise alignment of fibers in the single planar array configuration in the packaging of the WDM in accordance with the present invention. The fibers **209b–209d** are disposed within a set of V-grooves **701b–701d**, pre-cut or pre-formed within a face of the fiber alignment block **702**. Preferably, the alignment block **702** is fabricated from silicon and the V-grooves **701b–701d** are formed by well-known photolithographic masking and etching processes. The fiber **204** is disposed out of the plane of the set of fibers **209b–209d** and is held securely in place by either an opposing pressure plate, by a set of adjacent non-light transmitting fibers, or by some other securing mechanism (not shown). The long axis of fiber **204**, in general, makes an angle of 2ϕ with respect to that of the fiber with which it is in contact (FIG. **2b**), where the situation in which $2\phi=0$ is also permitted (FIG. **7c**). When the double planar array configuration (FIG. **7b**) is utilized, additional fibers **213a–213c** are disposed to either side of fiber **204** in substantially the same plane as fiber **204**.

FIG. **7d** illustrates an end view and a side view of the fiber alignment block **702** in the packaging of the WDM in accordance with the present invention. Each one of the set **209a–209n** of fibers is disposed within a respective one of the V-grooves **701a–701n**. The fibers are securely held in place within the V-grooves by epoxy or other adhesive and/or by a pressure plate (not shown) such that at least one

plane of fibers is parallel to the top face of the fiber alignment block **702**. One end face **711** of the fiber alignment block **702** is cut at a 60° angle (that is, a 30° angle with respect to the parallel axes of the fibers of the set **205** of fibers) and the end faces of the fibers of set **209a–209n** are disposed in alignment with the face **711**. In operation, the end face **711** faces the grating block **300**. A recess **712** is disposed at the opposite end of the fiber alignment block **702** from face **711** to provide strain relief for the fibers.

FIG. **7e** illustrates a perspective view of the assembled packaging of the WDM in accordance with the present invention. It is to be understood that the grating block **300** is disposed within the outer protective tube or sleeve **602** as illustrated in greater detail in FIG. **6**. Also, the set **205** of fibers (not shown) comprising fiber **204** and fibers **209a**, **209b**, etc. and, optionally, fiber **212** and fibers **213a**, **213b**, etc. . . . , is secured to the fiber alignment block **702**. The fiber alignment block **702** is positioned within an end cap **720** such that the angled face **711** of the block **702** and the ends of the fibers of set **205** face towards the grating block **300**. The end cap **720** provides freedom for lateral and angular adjustment of the disposition of the plane of the top face of the fiber alignment block **702**. During assembly, these adjustments are carried out so that the set **205** of fibers is in its optimal orientation with respect to the grating **302**. Subsequent to such adjustments, the fiber alignment block **702** is secured to the end cap **720** by epoxy, solder, or other securing mechanism or adhesive and the end-cap **720** is secured to the sleeve **602**. The final package is thereby hermetically sealed to protect the internal parts from environmental stresses or changes.

An improved packaging for a grating-based wavelength division multiplexer has been disclosed. A preferred embodiment of a packaging comprises a concave holographic reflection grating with an alignment surface, a first sleeve or cylinder with a three point mount for contacting the concave holographic reflecting grating and alignment surface, a pin or plate to align the alignment surfaces of the grating and the first sleeve or cylinder, and a second sleeve or cylinder with a spring-loaded holding mechanism in contact with the back side of the grating substrate. This packaging affords a quick, easy, precise and reproducible positioning and alignment of grating block. Thus, the wavelength division multiplexer is minimized in size while also reproducibly assembled with perfect alignment in a minimal amount of time.

Although the present invention has been described in accordance with the embodiments shown, one of ordinary skill in the art will readily recognize that there could be variations to the embodiments and those variations would be within the spirit and scope of the present invention. Accordingly, many modifications may be made by one of ordinary skill in the art without departing from the spirit and scope of the appended claims.

What is claimed is:

1. A package for a wavelength division multiplexer (WDM), comprising:
 - a grating comprising an alignment surface;
 - a first sleeve comprising a mount, the mount capable of contacting the grating; and
 - an alignment plate coupled to an outer surface of the first sleeve, wherein the alignment plate is contacting the alignment surface of the grating.

2. The package of claim 1, wherein the grating comprises a substrate plate, the substrate plate comprising:
a concave holographic grating surface; and
the alignment surface at an oblique angle to the grating surface. 5
3. The package of claim 2, wherein the substrate plate comprises a low-thermal-expansion substrate.
4. The package of claim 2, wherein the grating surface diffracts light such that the grating surface operates in a Littrow configuration. 10
5. The package of claim 2, wherein the grating surface comprises a reflective concave surface in a geometric form of a spherical cap.
6. The package of claim 5, wherein a grating axis of the grating surface is substantially perpendicular to a chord to the grating surface at a center of the spherical cap. 15
7. The package of claim 2, wherein the substrate plate further comprises:
a back surface opposite to the grating surface, wherein the back surface is substantially flat and substantially perpendicular to a grating axis of the grating surface. 20
8. The package of claim 1, wherein the first sleeve comprises a low-thermal-expansion material.
9. The package of claim 1, wherein the first sleeve is cylindrical in cross-section. 25
10. The package of claim 1, wherein the first sleeve comprises:
a slanted surface at an end of the first sleeve;
the mount coupled to the slanted surface; and
a slot on the outer surface of the first sleeve coupled to the alignment plate. 30
11. The package of claim 10, wherein the slanted surface is disposed at an angle such that an axis of the first sleeve is substantially parallel to a Littrow axis of the grating. 35
12. The package of claim 10, wherein the mount comprises a plurality of mounting pins.
13. The package of claim 1, further comprising:
a second sleeve, wherein at least a portion of the grating, the first sleeve, and the alignment plate are capable of residing within the second sleeve. 40
14. The package of claim 13, wherein the second sleeve comprises:
an open end;
a sealed end opposite to the open end; and
a holding mechanism coupled to the sealed end and residing within the second sleeve, wherein the holding mechanism is capable of applying force to the grating to place the grating into proper alignment with the mount and the alignment plate. 50
15. The package of claim 14, wherein the holding mechanism is spring-loaded.
16. The package of claim 13, further comprising:
an end cap coupled to an open end of the second sleeve; and
a fiber alignment block coupled to the end cap and optically coupled to the grating. 55
17. The package of claim 16, wherein the fiber alignment block comprises:
a plurality of fibers;
a plurality of grooves for holding the plurality of fibers;
an angled end face facing the grating; and
a recess at an end opposite to the angled end face. 65
18. A method for packaging a WDM, comprising the steps of:

- (a) providing a substrate plate, the substrate plate comprising:
a grating surface, and
an alignment surface at an oblique angle to the grating surface;
- (b) providing a first sleeve, the first sleeve comprising:
an alignment plate at an outer surface of the first sleeve, and
a mount coupled to an end of the first sleeve; and
- (c) coupling the substrate plate to the first sleeve, wherein the grating surface contacts the mount and the alignment surface contacts the alignment plate, wherein the grating surface has a desired alignment.
19. The method of claim 18, wherein the desired alignment allows the grating surface to diffract light such that the grating surface operates in a Littrow configuration.
20. The method of claim 18, further comprising:
(d) placing the coupled substrate plate and first sleeve into a second sleeve.
21. The method of claim 20, further comprising:
(e) engaging a back surface of the substrate plate with a holding mechanism, wherein the holding mechanism applies force to the back surface such that the grating surface and the first sleeve have the desired alignment.
22. The method of claim 21, further comprising:
(f) coupling an end cap to the second sleeve, wherein the end cap comprises a plurality of fibers, wherein the plurality of fibers are optically coupled to the grating surface.
23. A package for a WDM, comprising:
a substrate plate, comprising:
a grating surface, and
an alignment surface at an oblique angle to the grating surface;
a first sleeve, comprising:
a slanted surface at an end of the first sleeve,
a mount capable of contacting the grating surface and coupled to the slanted surface, and
a slot on an outer surface of the first sleeve; and
an alignment plate coupled to the outer surface, wherein the alignment plate is contacting the alignment surface.
24. The package of claim 23, wherein the grating surface diffracts light such that the grating surface operates in a Littrow configuration. 45
25. The package of claim 23, wherein the grating surface comprises a reflective concave surface in a geometric form of a spherical cap.
26. The package of claim 25, wherein a grating axis of the grating surface is substantially perpendicular to a chord to the grating surface at a center of the spherical cap.
27. The package of claim 23, wherein the substrate plate further comprises:
a back surface opposite to the grating surface, wherein the back surface is substantially flat and substantially perpendicular to a grating axis of the grating surface.
28. The package of claim 23, wherein the slanted surface is disposed at an angle such that an axis of the first sleeve is substantially parallel to a Littrow axis of the grating surface.
29. The package of claim 23, wherein the mount comprises a plurality of mounting pins.
30. The package of claim 23, further comprising:
a second sleeve, wherein at least a portion of the substrate plate, the first sleeve, and the alignment plate are capable of residing within the second sleeve.
31. The package of claim 30, wherein the second sleeve comprises:

an open end;
 a sealed end opposite to the open end; and
 a holding mechanism coupled to the sealed end and
 residing within the second sleeve, wherein the holding
 mechanism is capable of applying force to the substrate
 plate to place the grating surface into proper alignment
 with the mount and the alignment plate. 5
32. The package of claim **31**, wherein the holding mecha-
 nism is spring-loaded.
33. The package of claim **31**, further comprising: 10
 an end cap coupled to an open end of the second sleeve;
 and
 a fiber alignment block coupled to the end cap and
 optically coupled to the grating. 15
34. The package of claim **33**, wherein the fiber alignment
 block comprises:

a plurality of fibers;
 a plurality of grooves for holding the plurality of fibers;
 an angled end face facing the grating surface; and
 a recess at an end opposite to the angled end face.
35. A system, comprising:
 a fiber optic transmission system; and
 a WDM optically coupled to the fiber optic transmission
 system, wherein a package of the WDM comprises:
 a grating comprising an alignment surface;
 a first sleeve comprising a mount, the mount capable of
 contacting the grating; and
 an alignment plate coupled to an outer surface of the
 first sleeve, wherein the alignment plate is contacting
 the alignment surface of the grating.

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